2011

Integrating Technology and Problem-based Learning: A Mixed Methods Study of Two Teacher Professional Development Designs

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Abstract

This article describes two consecutive enactments of technology-oriented teacher professional development designs, aimed at helping teachers find high-quality online learning resources and use them in designing effective problem-based learning (PBL) activities for their students. To align with current professional development prescriptions, in the first enactment, teachers learned PBL design skills concurrently with technology skills. Following aspects of design-based research, the professional development theory, participant feedback, and results from the first enactment informed the design of the second. In this second enactment, technology skills were separated and presented prior to learning about PBL. Results from a mixed-methods study of impact indicated that both professional development enactments were associated with large increases in teacher knowledge, experience, and confidence with regards to technology use and integration. Variations in the level of PBL usage by teachers in their activities, and the degree to which they discuss PBL and technology integration are presented alongside limitations, practical significance, scholarly significance, and planned future work.

Introduction

The rapidly evolving CyberLearning Infrastructure (Ainsworth, Honey, & Johnson, 2005; Pea et al., 2008) provides instant access to a growing network of high quality, open access online resources for teaching and learning. Resources available through this networked environment include innovative curricula, teacher-created lesson plans, as well as interactive tools such as visualizations and simulations that use real-world datasets (Barker, 2009; McArthur & Zia, 2008). When this technical infrastructure is combined with Web 2.0 functionality, the intended result is a collaborative network for teaching and learning transcending location, time, and educational context. This allows users (e.g., researchers, content developers, teachers, and students) to access, create, connect, and share knowledge in ways that can fundamentally transform educational practice and deepen learning in the disciplines (Greenhow, Robelia, & Hughes, 2009).

However, within this seemingly boundless environment, several contextual factors limit the extent to which teachers utilize and contribute to these online environments and resources (Collins & Halverson, 2009; Hanson & Carlson, 2005; Kramer, Walker, & Brill, 2007; Recker, Dorward, Dawson, Halioris et al., 2005). In particular, the literature has identified several general barriers that prevent teachers from using online environments in effective and transformative ways. Some barriers are due to the technical infrastructure, including slow Internet connections, outdated technology, and limited student access (Barker, 2009; Recker, 2006). Research also suggests that teachers turn away from online environments because of poor usability design, concerns about the quality and accuracy of online resources, and the time required to filter through the large quantity of unranked search results (Carlson & Reidy, 2004; Madden, Ford, Miller, & Levy, 2005; Perrault, 2007; Sumner, Khoo, Recker, & Marlino, 2003).

In addition to these barriers, the successful integration of online resources is influenced by teachers' knowledge, experience, approaches to teaching and learning, and information literacy skills (Chen & Doty, 2005). In terms of knowledge, teachers must possess pedagogical knowledge and content knowledge in order to successfully integrate technology into teaching. This encompasses knowledge of the subject matter as well as the best use of various pedagogical approaches (Ferry et al., 2005). For example, while pedagogical approaches such as inquiry learning and problem-based learning (PBL) are becoming more prominent in K-12 classrooms and teacher education (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006; Murray-Harvey & Slee, 2000), their use has not yet become widespread (Ertmer & Simons, 2006). Lastly, in an era of overabundance of information, information literacy has also become a critical skill for teachers, though it is often lacking (Perrault, 2007). This encompasses the ability to exercise critical thinking in order to evaluate, integrate, and make effective use of information (Williams & Coles, 2007). Teacher professional development has long been used as a way to increase teachers' knowledge and skills, and many studies have demonstrated its positive effects on instructional practices and student learning (Borko, 2004). However, while much is known about characteristics of effective professional development in general (e.g., intensive, sustained, job-embedded, focused on content, active, and collaborative), these characteristics are not precise enough to guide practice (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Means, Murphy, Javitz, & Toyama, 2004; Wayne, Yoon, Zhu, Cronen, & Garet, 2008). Further, there is a dearth of studies that examine long-term impacts of technology-oriented professional development (Lawless & Pellegrino, 2007).

The purpose of this research is to develop and test a PBL technology-oriented professional development that helps teachers find high-quality online learning resources and use them to design effective PBL activities for their students. To empirically investigate unexplored variations of professional development prescriptions, in the first enactment teachers learned how to design PBL activities concurrently with the technology skills (tech-concurrent PBL). Then, following aspects of user-centered design (Nielsen, 1993) and design-based research (Design-Based Research Collective, 2003), professional development theory, participant feedback, and results from the first enactment informed the design of the second enactment. In this enactment, technology skills were presented prior to learning about PBL (tech-prior PBL). Results from a mixed-method study of professional development impact for both enactments are reported in terms of teachers' knowledge, confidence, behaviors, experience, and the level of PBL integration in activities designed for students. To support investigation of the professional development enactments, the following research questions were addressed:

1) To what extent do professional development participants design activities in the IA and then use them in classroom?
2) To what extent do professional development participants show changes in their knowledge, experience, and confidence in technology integration in teaching?
3) To what extent do professional development participants use PBL in their IA projects?
4) How do professional development participants describe their technology integration and use of PBL?

The next section of this article describes the inquiry-based approach, PBL, that teachers learned in the professional development. In addition, prior research on technology-oriented professional development is reviewed. It then describes the technology context for the professional development, the Instructional Architect. This is followed by a description of the two professional development enactments, the research design and methods for investigating their impact, and results. The article concludes with a discussion on limitations, practical significance, scholarly significance, and planned future work.

Literature Review

Problem-Based Learning

PBL is a well-established inquiry-oriented instructional method, originally developed in medical education, and now used in K-12 and higher education in both formal and informal settings (Savery, 2006). In PBL, learners acquire knowledge through engaging with authentic and challenging problems (Barrows, 1986; Barrows & Tamblyn, 1980; Savery, 2006). Typically, learners operate in small groups to solve these authentic problems using resources made available to them. The instructor acts as a facilitator, provides scaffolds and coaching, and models the kinds of meta-cognitive questions and strategies that students are then expected to do on their own (Hmelo-Silver & Barrows, 2008). Each problem cycle concludes with a reflection phase, in which learners discuss the efficacy of the information obtained and their solution strategies (Barrows, 1986).

Over time, several of the institutions utilizing PBL have adapted the approach to fit their own unique needs (Barrows, 1996). In this research, we define PBL as consisting of: 1) carefully selected and sequenced authentic problems, 2) a learner-centered approach, 3) teachers acting as facilitators or guides, and 4) learners working in small groups to solve problems, gather information, report findings, and reflect. This definition forms a baseline for all facets of our work, with adaptations or changes noted.

Overall, research shows that PBL is successful in promoting student learning. In addition to recent qualitative work (e.g. Ertmer, Glazewski et al., 2009) in the area of K-12 PBL use with technology integration, there is a long history of quantitative research across disciplines and educational levels. Meta-analyses of the quantitative research indicate PBL students learn more, particularly when assessing beyond the knowledge level (Dochy, Segers, Van den Bossche, & Gijbels, 2003; Gijbels, Dochy, Van den Bossche, & Segers, 2005; Walker & Leary, 2009). Further, there is agreement across several meta-analyses that PBL students retain more of what they learn (Strobel & Barneveld, 2009) over time. Quantitative results of PBL studies specific to K-12 educators are even more dramatic but are few in number. Of the available research, some attempted to improve conceptual and cognitive teaching practices (Derry et al., 2006; Murray-Harvey & Slee, 2000; Park & Ertmer, 2007). The remainder used PBL to teach skills, including visual literacy (Shoffner & Dalton, 1998) and general technology skills (Gulseçen & Kubat, 2006). Across all five quantitative studies in which teachers learned through PBL, gains were large and in favor of the PBL intervention ($d = .66$). Only one of the studies appeared to not only teach a combination of pedagogy (PBL) and technology skills, but also promote and investigate subsequent use of PBL by teachers (Park & Ertmer, 2007). Clearly, more work in this area is needed.

Teacher Professional Development

Prior literature suggests that we know little about what teachers learn from engaging in professional development, or how it impacts students' learning and engagement (Fishman, Marx, Best, & Tal, 2003; Lawless & Pellegrino, 2007; Means et al., 2004; Wayne et al., 2008). Ideally, professional development should change teachers' knowledge, beliefs, attitudes, and behaviors, because these correlate with classroom practice, thereby influencing students' learning (Fishman et al., 2003). Yet a recent review of technology-oriented professional development notes the lack of rigorous studies examining the links between teacher professional development experiences, classroom practices, and resulting impacts on students (Lawless & Pellegrino, 2007).

Prescriptive approaches targeted at technology-oriented professional development do exist. One example is learning by design (Koehler & Mishra, 2005a), which advocates engaging teachers in meaningful design problems in an attempt to improve their use of technology, to facilitate their adoption of pedagogical practices, and to increase their content knowledge (Koehler & Mishra, 2008). In learning by design, teachers acquire relevant skills and knowledge as they find solutions to their design problem. While empirical studies, descriptions, and summaries of learning by design professional development enactments exist (Koehler & Mishra, 2005a, 2005b; Koehler, Mishra, & Yahya, 2007; Koehler, Mishra, Hershey, & Peruski, 2004), more research is needed. For example, fundamental assumptions of learning by design, such as the best ways to concurrently address technology, pedagogy, and content knowledge, remain untested.

Note that *Learning by Design*™ is also the name of a trademarked instructional approach, incorporating project, problem, and case-based learning to promote student science learning (Kolodner et al., 2003). Here, we use learning by design as defined by Koehler and Mishra (2008) because their focus, like ours, is on teacher learning and professional development.

Technology Context: The Instructional Architect

The technology context for the professional development is the Instructional Architect (IA.usu.edu), a lightweight, web-based tool developed for supporting authoring of simple instructional activities using online learning resources in the National Science Digital Library (NSDL.org) and on the Web (Recker, 2006; Recker et al., 2005). With the IA, teachers are able to search for, select, sequence, annotate, and reuse online learning resources to create instructional web pages, called IA projects. These IA projects can be kept private (private-view), or made available to only their students (student-view), or to the wider Web (public-view). Figure 1 shows portions of two teacher created IA projects.

Figure 1a. Screenshot of an IA project, which exhibits several PBL elements.

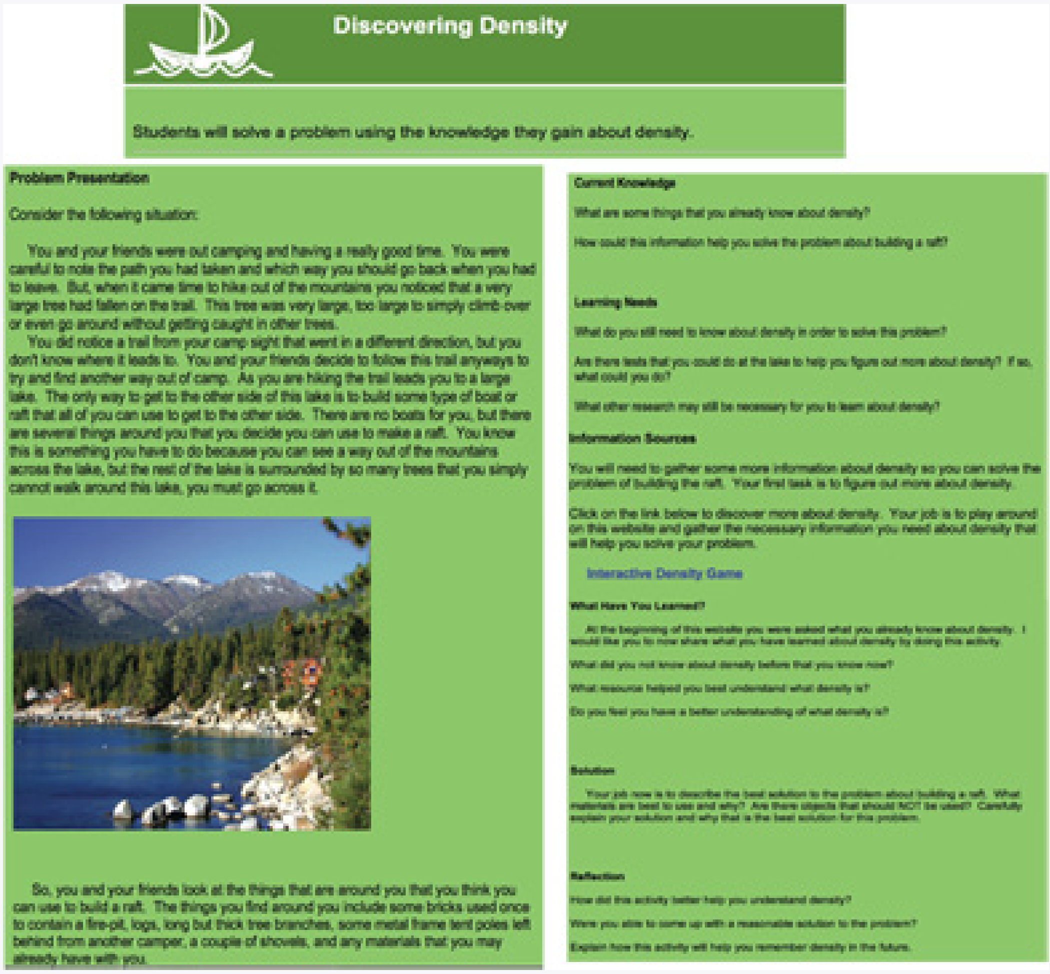
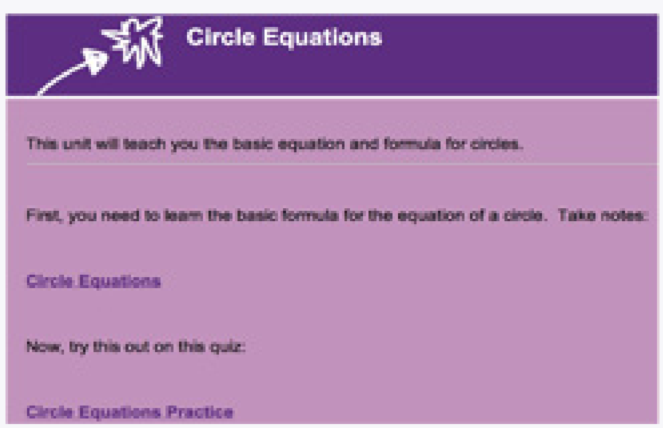


Figure 1b. Screenshot of an IA project, which includes instructions for each link.



To use the IA, a teacher must first register by creating a free IA account, which provides exclusive access to his/her saved resources and projects. After logging in, the IA offers two major usage modes: **resource management** and **project management**. In the resource management mode, teachers can search for and store links to NSDL resources, web resources, and other users' IA projects. These links are added to teachers' personal collections within the IA.

Within the IA's project management interface, teachers only need to enter an IA project's title, overview, and content, and the IA system generates a webpage dynamically. The teacher's collection of resources is listed on the left side of the screen, and links to resources can be embedded in to an IA project.

An IA project can be marked as public, student-view, or private. Anyone can visit a public IA project, students can access their teachers' student-view IA projects through their student accounts, and private IA projects are only viewable by the owner. All public IA projects are saved under the Creative Commons' free to share and free to remix license. Any registered teacher can make a duplicate of any public IA project by clicking the copy button at the bottom of the webpage. In this way, the IA provides a service level for supporting a teacher community around creating and sharing instructional resources and activities.

Evaluation has been ongoing since the IA was launched in 2002. Interview and survey data collected from IA users addresses the IA's impact on teacher knowledge, experience, and confidence in using online resources and the IA, as well as possible ways of improving the IA's user interface (Recker, 2006; Recker et al., 2005). Overall, users are positive about the value of the IA and generally recommend the IA to other teachers.

In recent years, IA's evaluation efforts have been expanded to include web usage analyses (Khoo et al., 2008). Since 2005, over 6,600 teachers have registered with the IA, more than 13,600 IA projects have been created, and 61,000 online resources have been added to the database. As of 2006, public IA projects have been viewed over 1.5 million times.

Enactment 1: Technology Concurrent PBL Professional Development Design

To address both the underutilization of online environments and resources and to promote their transformative use, we developed a technology and inquiry-oriented teacher professional development design. In our design, teachers learn to design PBL activities that engage students in solving authentic problems using online learning resources. To support teachers as designers (Angeli & Valanides, 2005) of activities using online resources, teachers learn to use the Instructional Architect.

The first professional development enactment, dubbed tech-concurrent PBL, was implemented as a series of two workshops, conducted as face-to-face sessions over three months, with in-between classroom activities. Incorporating important, research driven characteristics (Desimone, 2009; Wayne et al., 2008), each enactment is sustained, centered on authentic design problems, content focused, active, and collaborative. As advocated by both PBL and best practices in teacher technology-oriented professional development (Lawless & Pellegrino, 2007), participants engage with authentic and complex design problems in their own teaching, generate solutions, and reflect with their peers on barriers and successes.

The tech-concurrent PBL professional development focused on the following technology skills: 1) finding and collecting online learning resources, and 2) creating activities (IA projects) using discovered online resources for students including copy/paste, and text formatting. The pedagogical content focused on learning to design and integrate PBL activities for students. Professional development participants were encouraged to utilize PBL with their students only if they felt it aligned with their self-selected design problem, the needs of their students, and their own beliefs about teaching and learning.

Aligning with the connected nature of learning by design, teachers in this first enactment of our professional development design learned PBL design skills concurrently with technology skills. Specific PBL elements used in the professional development design include group design work, engagement with authentic problems, and reflection at the individual and group level. Pedagogy skills were focused squarely on PBL including critical elements of the approach, a discussion of how to design for PBL, crafting appropriate problem statements and selecting appropriate content areas for PBL, and finally barriers to implementing PBL and how to overcome them.

Enactment 1: Informing a Cycle of Design Experimentation

Following aspects of design-based research, the professional development theory, study results, and participant feedback were examined to inform a cycle of design experimentation (Design-Based Research Collective, 2003). In particular, eight participants in a post-professional development focus group indicated that learning new pedagogy and technology skills concurrently was too difficult. Their recommendation was to introduce pedagogy and technology skills separately (Robertshaw, Walker, Recker, Leary, & Sellers, 2010). This sentiment echoes PBL research suggesting that PBL can be challenging (Arambula-Greenfield, 1996), to the point of requiring more time and effort on the part of learners (Ertmer et al., 2009; Surlekar, 1998). In response to this literature and the needs of our participants, the second enactment of the professional development design departed from the recommendations of learning by design and separated learning technology skills from learning PBL. Table 1 shows details and length for both enactments of the workshop.

Table 1. Key activities for the two Technology Development designs.

Technology concurrent with PBL **2.5 hour workshops**	**Technology prior to PBL** **2 hour workshops**
Workshop 1	
• Divide into small groups • Demonstrate use of the IA • Participants select design problem • Introduce online resources and IA • Engage in example PBL activity • Initiate discussion about PBL • Review critical elements of PBL • Groups begin to design IA project(s) *Technical skills (60 minutes)* *Pedagogical skills (60 minutes)* *Design time (15 minutes)*	• Demonstrate use of the IA • Introduce online resources and IA • Walk through sample project creation • Participants select design problem • Individuals design IA project(s) *Technical skills (60 minutes)* *Pedagogical skills (0 minutes)* *Design time (45 minutes)*
Between workshops	
• Design and implement IA project(s) • Reflect on barriers and successes	• Design and implement IA project(s) • Reflect on barriers and successes
Workshop 2	
• Review use of the IA • Small and large group discussion of implementation experiences • Participants revisit instructional problem *Technical skills (30 minutes)* *Pedagogical skills (60 minutes)* *Design time (45 minutes)*	• Review use of the IA • Small and large group discussion of implementation experiences • Engage in example PBL activity • Review critical elements of PBL • Groups begin to design new IA project(s) *Technical skills (15 minutes)* *Pedagogical skills (60 minutes)* *Design time (30 minutes)*
Between workshops	
	• Design and implement IA project(s) • Reflect on barriers and successes
Workshop 3	
	• Small and large group discussion of experiences *Technical skills (15 minutes)* *Pedagogical skills (60 minutes)* *Design time (30 minutes)*

Enactment 2: Technology Prior To PBL Professional Development Design

Professional development activities in this second enactment covered similar material but also contained key differences. Specifically, in the first enactment, tech-concurrent PBL, participants learned needed technology skills by following the instructor's large group example exercises of searching, collecting, and adding resources while learning about PBL as an instructional approach. In the second enactment, tech-prior PBL, the same technology skills as the first enactment were learned separately and prior to PBL. For the tech-concurrent PBL enactment, total professional development time was five hours spread over two workshop meetings with in-between activities. The tech-prior PBL enactment met in three workshops for two hours each day and had an additional round of between workshop activities. Between workshop activities consisted of finishing IA designs, implementing the activity with students, and then reflecting on the implementation in the classroom in a reflection paper. In addition to pedagogical time devoted to learning about PBL, Figure 2 shows a summary of time devoted to technical skills (use of the IA), and time provided for participants to design instructional activities. Remaining time was devoted to discussion, administrative functions, and breaks.

Summary of Enactments

All workshop participants received PBL scaffolding in several forms. They received: 1) a "cheat sheet" hand-out, describing key features of problem-based learning, 2) a sample IA project exemplifying PBL, and 3) a PBL shell in the form of an IA project for teachers to copy and modify for their own use. The cheat sheet contained brief descriptions of PBL features that were covered in the workshop. The PBL shell and sample PBL IA project were designed to work together. For each main point in the PBL shell, an excerpt from the sample PBL project was provided as an example of the kind of material teachers might provide (for example, the problem presentation).

In both professional development enactments, participants learned how to use PBL in their teaching and were taught using a variation of PBL throughout the professional development. In particular, participants engaged in meaningful reflection on their work, consisting of both self and peer evaluation. They were exposed to and solved authentic problems, were primarily responsible for their own learning, and engaged in small group interactions. However, both professional development enactments had substantive variations from Barrows' definition of PBL (Barrows, 1986, 1996). The largest difference was the origin of the problem, with participants selecting a need for their own classrooms as opposed to having a design problem selected for them. This was a conscious trade-off between authenticity and content coverage. While a pre-selected problem might force participants to discover desired technical and pedagogical skills, teachers may not face that problem in their own classroom. As a result, they would be asked to design a problem solution for which they have no immediate use. Instead, teachers were asked to think of a current instructional need for their students, assuring authenticity for professional development participants.

The other difference from Barrows' definition was group work. *Tech-concurrent PBL* participants formed groups and worked on one initial design together. After receiving feedback from participants, we concluded that the authenticity gain of self-selected problems was lost when participants were asked to work on the problem of another teacher. Therefore, group activities in the *tech-prior PBL* group consisted solely of reflection on and evaluation of individually generated problem solutions, as well as group participation in the sample PBL activities.

Research Design and Methods

The research designs used to investigate the impacts of both professional development enactments (*tech-concurrent PBL, tech-prior PBL*) were identical and are presented in this section. For both enactments, a mixed method approach was used (Creswell, Clark, Gutmann, & Hanson, 2003). Quantitative research was the primary emphasis, used to address the first three research questions. The quantitative portion is aligned with two consecutive one-group pre-test post-test designs (Campbell & Stanley, 1963) where the control group is seen as an alternative treatment. Qualitative data were gathered in parallel and analyzed to address the final research question (Johnson & Onwuegbuzie, 2004; Teddlie & Tashakkori, 2009). More specifically, a case study was conducted. Purposeful sampling (Yin, 2003) was used with the goal of finding representative participants based on the quantitative data. PBL alignment scores and a combination of self-reported post-survey scores about experience, knowledge, and confidence with technology integration were used to rank participants. To assure participants that represented the full range of teacher experiences one participant was selected from the *lower*, *middle*, and *upper* third from each of the two professional development enactments (total N = 6).

Participants

All participants consisted of classroom teachers drawn from the same rural school district. Participants received one university credit for completing all professional development requirements. The *tech-concurrent PBL* enactment took place first (N=23), while the *tech-prior PBL* enactment (N=19) was implemented second. Mortality for the study was high due to participants dropping out of the professional development. A total of 22% (N=5) left tech-concurrent PBL and 30% left (N=6) *tech-prior PBL*.

Data Sources

The following data sources were collected as part of each professional development enactment (see Table 2).

IA usage data

The IA system automatically collects data of teachers' use of the IA (Khoo et al., 2008), including number of logins, IA project visits, online resources used, and IA projects created. These data were used as a measure of professional development impact on behavior.

Table 2. Professional development enactments and data collections points.

Technology concurrent with PBL 2.5 hour workshops	Technology prior to PBL 2 hour workshops
Workshop 1	
Pre-survey	Pre-survey
Between workshop activities	
• IA usage data • PBL alignment of IA project • Reflection paper	• IA usage data • PBL alignment of IA project • Reflection paper
Workshop 2	
Post-survey	
	Between workshop activities • IA usage data • PBL alignment of IA project • Reflection paper
	Workshop 3 Post-survey

Teacher pre- and post-survey

We collected pre/post data on teachers' experiences through an online survey administered at the start and end of the professional development. The survey consisted of nine Likert scale (0= "strongly disagree"; 4= "strongly agree") items, drawn from Becker (2000) and designed to measure professional development impact on knowledge, experience, and confidence with technology integration.

PBL Alignment of IA projects

As part of professional development activities, participants were asked to design PBL activities using the Instructional Architect and then implement them in their classrooms. To measure participant alignment of their IA projects with PBL, an established rating scale was employed (Walker & Shelton, 2008). This scale, shown in Table 3, was used to measure the presence or absence of 14 PBL elements in 4 general categories in participants' IA projects.

Raters consisted of research team members who were blind to the source of the IA project. Each project received three ratings from a randomly selected pool of judges. A one-way random effects intra-class correlation (ICC) was calculated to determine the reliability of raters for the available data (Shrout & Fleiss, 1979). The resulting ICC of 0.89 indicates a substantial level of inter-rater reliability for these data.

Once rated, median values for each project were computed from the three ratings and used in subsequent analyses as the PBL score. Note that the scores only apply to level of PBL elements as reflected in IA projects, and thus are likely an under-estimate of actual PBL use in the classroom. For example, participants may have incorporated small group interactions without making explicit mention of this in their IA project.

Table 3. Problem-based learning alignment rating scale.

PBL Element	Description
Authentic Problems	Problems are complex (cross-disciplinary).
Authentic Problems	Problems have multiple solution paths.
Authentic Problems	Problems are ill-structured.
Authentic Problems	Problems are likely to be encountered in professional practice.
Learner Centered	Learners generate objectives from given (and unresolved) problems.
Learner Centered	Learners are prompted to locate resources (content experts, reference books, journals articles) that will assist in problem resolution.
Learner Centered	Learners are prompted to utilize resources (content experts, reference books, journals articles) that will assist in problem resolution.
Learner Centered	Learners engage in self and/or peer assessment of problem solving performance within their group.
Teachers as Facilitators	Facilitators model and prompt students with meta-cognitive questions that assist in problem resolution.
Teachers as Facilitators	Facilitators are guides.
Small Group Interaction	Learners interact in groups.
Small Group Interaction	Divide and conquer.
Small Group Interaction	Learners share and discuss their findings.
Small Group Interaction	The group evaluates the utility of the acquired knowledge in solving the problem.

Reflection papers

After implementing each of their IA projects with their students, participants were asked to write a reflection paper, addressing the following prompts:

1. Describe the IA project implemented with students.
2. Describe the successes and difficulties encountered in designing and implementing the activity.
3. Discuss the teaching approach or approaches used in the IA project.

Data analysis

For the quantitative portion, descriptive statistics and effect sizes were calculated to address the magnitude of effect and examine the practical significance (Ferguson, 2009). Because of the substantive differences between workshop enactments, an emphasis is placed on within-group changes as represented by effect size differences, rather than inferential statistics for between-group comparisons.

Although not an attempt at grounded theory, the constant comparative analysis technique from Corbin and Strauss (2008) was utilized to examine the six participants' reflection papers. In the first stage of analysis, two independent coders used open coding to look for emerging themes. In the second stage, axial coding was used to collapse themes generated from the open coding process in two stages. In the first stage of axial coding, data were collapsed into focused categories (for example, resource access, small group work, or technology knowledge). In the second stage of axial coding, themes were collapsed into technology integration or problem-based learning. In the qualitative results, quotes are presented with each participant's professional development enactment (*tech-concurrent PBL* or *tech-prior PBL*) and placement (*lower*, *middle*, or *upper*).

Results

Quantitative results are presented to address the first three research questions using the following participant data sources: 1) IA usage data, 2) knowledge, experience, and confidence in technology integration as measured by pre/post-surveys, and 3) alignment of IA projects with PBL elements. Research question four is addressed with a qualitative analysis of participants' reflection papers.

Research Question 1: IA usage

IA usage analyses show a large number of logins to the IA, created IA projects, online resources used, and project visits (see Table 4). These measures suggest that participants successfully used the IA to design activities and use them with students.

Table 4. Participants' activities as measured by IA usage data.

	M	*SD*	*Max*
Tech-concurrent PBL (*N* = 18)			
Number of participant logins to the IA	26.72	21.53	92
Number of IA projects created	6.68	4.88	17
Number of online resources used	27.52	27.82	105
Number of visits per IA project (N > 1)	71.36	117.99	888
Tech-prior PBL (*N* = 13)			
Number of participant logins to the IA	27.50	17.96	72
Number of IA projects created	7.00	5.90	27
Number of online resources used	29.72	43.71	178
Number of visits per IA project (N > 1)	114.41	142.71	1724

Despite the additional round of between workshop activities, tech-prior PBL participants designed about as many (M = 7.00) projects as tech-concurrent PBL participants (M = 6.68). Both enactments showed a relatively high number of visits per project, indicating high student usage of the project and associated online learning resources. However, tech-concurrent PBL participants showed fewer visits per project (M = 71.36) than participants in the tech-prior PBL enactment (M = 114.41). Finally, as a glimpse of long-term impact, 14 (77%) of tech-concurrent PBL and 8 (61%) of tech-prior PBL participants were still active IA users 6 months after the conclusion of the professional development. Since professional development studies seldom report long-term impact data (Wayne et al., 2008), it is hard to know how these results compare.

Research Question 2: Participant Knowledge, Experience, and Confidence in Technology Integration

This research question addresses changes in the technology integration knowledge, experience, and confidence of professional development participants. Those changes appear to be substantial. Table 5 reports large pre-post gains in all areas for both enactments. Cohen (1988) describes effect sizes (d) of .8 as large, something that would be visible to a casual observer. All of the pre-post gains have effect sizes that are .88 or greater. Reported gains in experience are about the same for the tech-concurrent PBL (d = 1.11) and tech-prior PBL (d = 1.14) professional development participants. Gains are nearly or more than twice as large for the participants in second enactment, tech-prior PBL, for both knowledge (d = 1.56) and confidence (d = 1.86) when compared to participants in the first enactment, tech-concurrent PBL (d = 0.88). Effect size increases are due to a combination of larger mean difference, as well as substantially smaller standard deviations in the tech-prior PBL enactment.

Table 5. Participants' self-reports on technology integration knowledge, experience, and confidence

Enactment/Outcome	Pre-survey *M*	Pre-survey *SD*	Post-survey *M*	Post-survey *SD*	*d*
Tech-concurrent PBL (*N* = 18)					
Experience creating online lessons	1.44	1.25	2.72	0.96	1.11
Knowledge using technology in classroom	2.00	1.14	2.78	0.94	0.88
Confidence in teaching with technology	2.06	1.16	2.83	0.79	0.88
Tech-prior to PBL (*N* = 13)					
Experience creating online lessons	1.57	1.26	2.91	0.76	1.14
Knowledge using technology in classroom	1.83	0.90	2.83	0.55	1.56
Confidence in teaching with technology	2.08	0.76	3.00	0.58	1.86

Research Question 3: Alignment of IA projects with Problem-Based Learning

This research question examines the level of PBL alignment in participant-designed IA projects. Table 6 shows overall scores for each enactment on the presence of PBL elements in their IA projects. All of the scores were low and positively skewed with only a handful of participants scoring high.

Recall that tech-concurrent PBL participants only had one opportunity to design and implement IA projects after receiving a combination of technology and pedagogy training. As a consequence, there was no opportunity to examine change in these participants. Participants in the second enactment, tech-prior PBL, had two opportunities to design and implement: the first after the technology workshop (M = 1.54), and then a second after the second pedagogy workshop (M = 4.62). After the workshop on designing IA projects using PBL, participants in the second enactment more than doubled their use of PBL elements (d = 0.93). Either the sustained nature of the tech-prior PBL enactment, separating technology from PBL instruction, or the combination of both factors may have improved use of PBL elements.

Table 6. Overall level of problem-based learning elements in IA projects.

Enactment/Time	*N*	*M*	*SD*	*Max*
Tech-concurrent PBL				
after tech and PBL workshop	18	2.61	2.91	9
Tech-prior PBL				
after workshop 1	13	1.54	1.66	4
after workshop 2	13	4.62	4.37	14

Table 7 shows participants' use within their IA projects of PBL elements within the four different categories. Note that across both enactments, mean use of PBL elements in the different categories occurred in the same rank order. Specifically, the "authentic problem" category was most evident, followed by "learner centered," "teacher as facilitator," and "small group interaction." The fact that the "small group interaction" category had the lowest means is particularly surprising given that the "teacher as facilitator" category had a maximum of two points and thus would be expected to be lowest. As suggested earlier, participants may be implementing small group work with their students but did not explicitly mention this within their IA projects. Note that while both groups participated in a sample PBL activity from the student perspective and engaged in group reflection, thus reinforcing the principle of small group work. Tech-concurrent PBL participants, however, also engaged in collaborative design in small groups and perhaps received additional reinforcement of this principle.

Table 7. Scores in each category of problem-based learning in IA projects.

PBL Element (scale)	Tech-concurrent PBL			Tech-prior PBL (after workshop 1)			Tech-prior PBL (after workshop 2)		
	M	*SD*	*Max*	*M*	*SD*	*Max*	*M*	*SD*	*Max*
Authentic Problems (0-4)	1.17	1.54	4	0.77	0.93	2	1.92	1.66	4
Learner Centered (0-4)	1.00	1.03	3	0.54	0.78	2	1.46	1.33	4
Teacher as Facilitator (0-2)	0.28	0.57	2	0.15	0.38	1	0.62	0.87	2
Small Group Work (0-4)	0.17	0.38	1	0.08	0.28	1	0.62	1.33	4

Research Question 4: Participant Perceptions of Technology Integration and PBL

Participants from each enactment appeared to differ in their characterizations of technology integration and PBL. The following results are discussed in terms of the technology integration and problem based learning combined themes from the second round of axial coding.

Problem Based Learning

At the conclusion of the professional development, tech-prior PBL participants' comments appeared more focused on pedagogy than technology integration. A participant in the upper third of the tech-prior PBL enactment indicated through her reflection paper and IA project designs that the professional development was effective in helping her to learn about PBL. Her first IA project (before the workshop on PBL) consisted of a list of directions about how to use the provided links and directed students to go through the lesson individually. However, her second IA project used an authentic problem, included resources to be explored, showed evidence of her acting as a facilitator, and called on students to synthesize newly acquired knowledge to solve the provided problem. She focused on discussing PBL in her reflection paper and went as far as to read about PBL. She stated: "I love the idea of PBL. I see [Instructional Architect] could fit in nicely with this concept, and in fact, might help teachers be able to work together. I read an article suggesting how PBL can spread across the curriculum with several teachers working on the same problem."

In contrast, the participant from the upper third in the tech-concurrent PBL enactment incorporated less PBL into her IA project after receiving instruction in the method. While her reflection paper addressed technology integration at length, she did not indicate a full understanding about how PBL can be integrated into her technology practices. In discussing what she saw as a PBL oriented project she wrote "I would like to use my [Instructional] Architect project as a kind of guide for those students who show a special interest in filmmaking and want to help with postproduction and the more technical aspects of the production process (i.e. camera angles, etc.). That way they will already have some background when the time comes for them to start work on their own projects." It appears she did not intend to present the problem first to students and have them search for information to help them solve it, but instead wanted her learners to go through a largely information oriented set of tasks, obtaining background information before working on a project. Promoting authenticity and leading with the problem are both critical components of PBL, which were not evident in this participant's approach.

Technology Integration

The bulk of the discussion in reflection papers from both participants in the lower third of the two enactments did not focus on PBL, but rather focused on using the technology. Mrs. S, from the tech-concurrent PBL enactment, described her implementation with the following: "I used my project in the computer lab on our regular computer day. Students worked independently. They found it very easy to access and students loved knowing that Mrs. S. had found these games for them to effectively use." Mrs. B., from the tech-prior PBL enactment, discussed the ease of using the IA, along with three separate comments about issues of access to technology.

Looking beyond the similar lower third participants, tech-concurrent PBL participants tended to make more statements about technology integration. This is was reflected in both an increased frequency in the technology knowledge category, as well as more diverse comments covering nuances such as dissemination and alternatives. Tech-prior PBL participants appeared to engage more often in writing about PBL. For the most part, this represented an increase in frequency across the same categories as the tech-concurrent PBL enactment. The tech-prior PBL participants were the only ones to discuss resources, a critical component of PBL in which students are asked to find and utilize resources in pursuit of their problem solution.

The common experience of focusing on technology integration for both participants in the lower third of their respective enactments may speak to the broader technology integration literature. As found in prior research (Kramer et al., 2007), there may be common patterns in which baseline needs, such as infrastructure or professional development, have to be addressed before moving on to innovative pedagogies. For those who clearly met those baseline needs, the differences between enactments are all the more interesting. It may be that teachers who are knowledgeable, confident, and experienced with technology integration still benefit from focusing on one thing at a time, whether it is the new technology, in this case the Instructional Architect, or an innovative pedagogy.

Conclusion and Limitations

This article described two technology-oriented professional development enactments that help teachers find high-quality online learning resources and use them in designing effective PBL activities for their students. The two enactments explored variations in professional development design, in particular the mix of technology and pedagogy. Following aspects of user-centered design (Nielsen, 1993) and design-based research (Design-Based Research Collective, 2003), professional development theory, results, and participant feedback from the first enactment informed the design of the second.

To investigate the impact of the two professional development enactments, we presented results from a mixed-method study. Quantitative results from the study indicated that participants in both enactments showed large gains in terms of their knowledge, experience, and confidence after participating in their respective professional development enactments, with results from the second enactment, tech-prior PBL, showing larger effect sizes. IA usage data showed that participants designed activities using the IA, both during and, for some, up to six months after the professional development. IA usage data also showed that students of tech-prior PBL participants visited IA projects more often. The increased visits by students suggest a fundamentally student-centered approach to teaching and learning, and thus better alignment to PBL.

Improved PBL alignment is also evident in the scoring of IA projects. Tech-prior PBL participants finished with almost twice the PBL alignment score as tech-concurrent PBL participants. But the reasons for this remain unclear. With the benefit of an additional round of workshop and activities, this difference may simply reflect a more sustained approach as recommended in the literature (Lawless & Pellegrino, 2007). It may also be attributable to the primary motivation behind the design of the second workshop enactment, specifically reducing the complexity of the material by separating technology skills from the introduction of PBL.

Note that it is unclear if the differences are meaningful. Overall scores were quite low given the 14-point range of the scale. The most dramatic shift is two and a half points, taking participants from almost no usage of PBL to very little usage. Reasons for the low scores may be due to a rubric that lacks sensitivity. For example, while an authentic problem is a critical component of PBL, so is its cross-disciplinary nature. As such, IA projects would need to present problems that are cross disciplinary to score on the rubric, but would not get credit for a cross-disciplinary activity if it was not focused on a problem. Another possible explanation for low scores on PBL elements is that for most teachers, PBL represents a dramatic shift in practice (Ertmer et al., 2009).

According to the recommendations of learning by design (Koehler & Mishra, 2005a), teachers should acquire technology and pedagogy knowledge concurrently while engaging in meaningful problems. Although this study is small and has several limitations, those claims do not appear to be supported here in the quantitative data. Teachers from both enactments had positive changes in their knowledge, experience, and confidence about technology integration.

At least for PBL usage, the qualitative findings from analyzing data from 6 participants parallel the quantitative results. In particular, participants in the tech-concurrent PBL enactment engaged in a more in-depth and broader discussion of technology integration in their reflection papers, whereas participants in the tech-prior PBL enactment engaged in more discussion of PBL. Thus, the qualitative findings suggest that presenting technology-skills concurrently is preferred when the goal is to promote a more extensive and rich discussion of technology integration. If, however, the goal is to promote discussion of PBL, then making the professional development more sustained and separating the technology and pedagogy experiences is preferred. Additional research is needed to determine whether or not the ability to engage in more discussion is indicative of a deeper understanding and eventual use of these respective technology and pedagogy skills.

Limitations to this work include group random assignment and the potential for historical threats to validity. Teachers signed up for each workshop blind to the treatment, but there may have been factors, such as district budget cuts, that altered the nature of who participated. Data collection did not involve classroom observations; as a result, some measures—PBL alignment in particular—may not have accurately reflected the level of PBL usage in the classroom. Finally, there were several changes in professional development enactment features that may account for outcome differences. As noted above, the two professional development enactments differed in terms of the amount of time spent on the various activities, how sustained they were, the level of group work involved, and the number of time points for measuring PBL alignment. As such, direct comparisons between professional development enactments need to be interpreted with caution. Although the number of workshops varied, the time spent on technology skills (90 minutes) and learning PBL (120 minutes) was identical for both enactments. Many other elements were identical, including the scaffolds used for helping teachers design PBL activities, the sample PBL activities done in the workshops, the technology skills taught, and the prompts for reflection papers.

In part because of these limitations and in part because of our own variations on the approach, results from this study should not be taken as an indictment against learning by design. Prior learning by design research made note of technology being emergent and participant selected, whereas the technology tool for this study (the IA) was selected a priori. At first glance, the lack of content knowledge as an explicit component of the professional development also seems to depart from learning by design, but we note that there is precedent. Examples from prior studies also appear to de-emphasize content knowledge such as asking in-service teachers to create videos relating to their existing understanding of library sciences (Koehler & Mishra, 2005a). The professional development reported here also involved less group work and took less time. Prior studies of learning by design have been associated with university classes spanning an entire semester (Koehler & Mishra, 2005a, 2005b; Koehler et al., 2004). Replication work with a more sustained intervention and participant-selected technology is needed to permit more direct comparisons.

Future work includes examining the impacts on students when engaging them in PBL activities using online resources. Data collection is currently underway to support a Generalized Estimating Equation (GEE) model of student outcomes with teachers as the grouping variable. In addition, while the initial reliability of the PBL alignment rubric for these data is encouraging, it remains to be seen if that success can be repeated with other samples. Finally, classroom observations (Park & Ertmer, 2008) are needed to determine the congruence between teacher designs and how those designs are ultimately used in the classroom.

Acknowledgements

The authors would like to thank the study participants for their time and assistance. This material is based upon work supported by the National Science Foundation under Grant No. 0554440, and Utah State University. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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